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MASS SPECTROMETRIC MEASUREMENTS OF GAS COMPOSITION OF THE EARTHATMOSPHERE BY MEANS OF ROCKETS AND SATELLITES

( Mass-spektrometricheskiye izmereniya gazovogo sostava atmosfery

Zenli na raketakh i sputnikah)

Geomagnetizm i Aeronomiya

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11473ABSTRACT

Discussed is a method for measurement of the atmosphere's neutral composition with the help of a radiofrequency mass-spectrometer (RMS)\* on rockets and satellites. The essential difficulty of rocket measurements lies in the fact, that the apparatus reacts similarly on the direct flux of particles of an unperturbed composition, as on the reverse flux of those having undergone multiple collisions with the wall of the apparatus, and considerably impoverished by atomic constituents (recombination and surface reaction). As a result, data on atomic oxygen concentration obtained on rockets are underrated, while data on molecular oxygen concentration, as well as the values of the mean molecular weight of the air above 100 km are overrated. A method is proposed for measurement of the atmosphere neutral composition by means of the RMS mass-spectrometer on an Earth's artificial satellite, unhindered by the above-indicated difficulties.

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\* This designation has been transliterated.

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Geomagnetizm i Aeronomiya

COVER-TO-COVER TRANSLATION

One of the most important problems in all-round complex of investigations of physical conditions in the upper atmosphere and of its structural parameters in particular, is presently that of determination of terrestrial atmosphere composition at 100 km altitude and above. Intensive investigations in that region, mostly surveys by means of rockets, have been carried out for more than seven years. However, despite the successes already achieved, it must be recognized that the problem of gas composition at 100 km altitudes and above, is still far from being solved. The causes of this lag lie in the substantial difficulties encountered when conducting direct analyses of the composition with the help of mass-spectrometers of various types aboard rockets and satellites. As far as is known, mass-spectrometers, and in particular the so-called Bennett-type radiofrequency mass-spectrometer, constitute the only devices fit for such type of measurements.

The object of the present work is to call attention to certain substantial difficulties occurring in the use of radio-frequency mass-spectrometer as the analyzer of atmosphere's neutral composition, and to indicate ways of surmounting them.

Three fundamental directions, among the multiple aspects of the questions being solved in gas composition research, along which the work has been, and is likely to be carried out in the future, ought to be outlined here. As is well known, such directions are:

1. Measurement of the absolute content (of concentrations and partial pressures) of the basic atmosphere constituents — molecular nitrogen and

oxygen, and also the finding of the level of their dissociation, and of the degree of dissociation at various altitudes. In other words, direct determination of  $O_2$ ,  $O$ ,  $N_2$  and  $N$  concentrations, and determination of the mean molecular weight of the atmosphere at various altitudes.

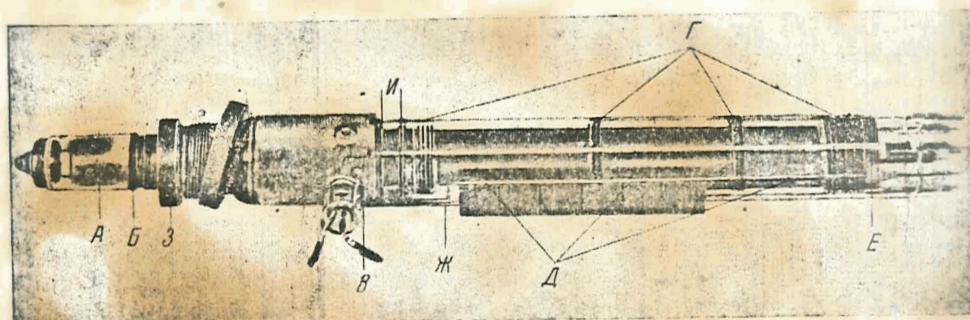
2. Analysis of the content of minor constituents of the atmosphere, and first of all of light gases — atomic (and possibly molecular) hydrogen and helium, and also of various chemically unstable compounds, such as hydroxyl  $OH$ , nitrogen oxide  $NO$ , etc.

3. Finding of the level of gravitational separation of gases, and study of the degree of their separation at various altitudes by way of analysis of the relative content of any two atmosphere constituents with different molecular weights. Argon and molecular nitrogen are usually analyzed on account of their greater content, their relative stability (for the nitrogen dissociation apparently does not begin below 200 km), and the substantial difference in molecular weights.

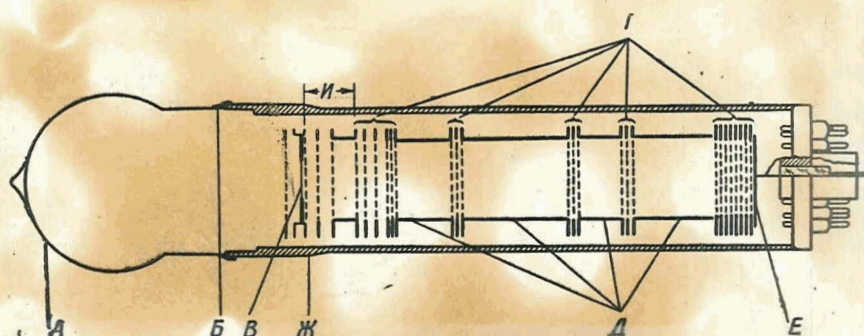
The mass-spectrometer may successfully solve the above-enumerated, as well many other problems of upper atmosphere layer physics. Nonetheless, at present only questions having bearing on gravitational separation of argon and molecular nitrogen provide somewhat complete and reliable answer by the method of radio-frequency mass-spectrometer [1, 2]. Data relative to nitrogen and oxygen dissociation, and also (but to a lesser degree) data on the content of minor and unstable admixtures do not reflect to a sufficient degree the factual state of the free atmosphere, and its true composition. This results unquestionable according to the following considerations.

Shortcomings of the Method. The following conditions must be fulfilled in case of mass-spectrometer use for the analysis of gas composition [3]: 1) gas molecules having undergone collision with the hot cathode or with hot metallic surfaces must not penetrate in the ionization region; 2) no superficial reactions are to take place. The fulfillment of these conditions is prerequisite to the analysis of the neutral composition, and it is particularly evident if chemically-active constituents are present in the gas mixture, such as molecular, and still more so — the atomic oxygen (or nitrogen). It is however just as evident that in radiofrequency mass -spectrometers applied heretofore in rocket investigations of atmosphere gas constituents, neither of these two requirements were fulfilled\*.

Figure 1, a next page represents a photograph of a mass-spectrometer tube applied in the research by USA investigators [1, 5], and Figure 1 presents a block-diagram of the mass-spectromer tube similar to that utilized in works [2, 6]. An ion source with gas ionization by slow electrons is present in both instrumentations. It is located inside the tube, while the incandescent cathode filament (spiral or straight), as well as the electrodes supporting it, are situated directly in the path of the incoming gas flow. It is clear that a specific (although possibly very small) percentage of entering particles will be interacting with the filament and with the hot electrodes. As a result of that, the amount of oxygen in the mixture will decrease (This is a known "combustion" phenomenon in mass-spectrometry, on the filament of the ionic source). Simultaneously, new molecules, heretofore not present in the atmosphere, such as CO and CO<sub>2</sub>, with  $M = 28$  and  $M = 44$  atomic unit masses, must appear. This is observed



a



б

Fig. 1, a — Tube of the radiofrequency mass-spectrometer utilized in the research work by U.S.A. explorers.

б — block-diagram of the tube of the mass-spectrometer used in USSR. А — breakable or removable protective hood. Б — cross-section of the mass-spectrometer's inlet. В — Filament of the ion source cathode that becomes incandescent. Г — Wolfram wire grids on braided or nuckeliferous rings. Д — Space drifts metallic screens. Е — Ion collector. Ж — Bulb of the tube. З — Tube's flanged joint. И — Ionization space of the ion source.

in reality. Mass  $M = 44$  is registered during atmosphere composition measurement by means of rockets in amounts considerably exceeding (several times) the  $\text{CO}_2$  content of the air near the Earth's surface [1, 2, 6]. Because of the closeness of molecular weights, carbon monoxide  $\text{CO}$  cannot be resolved with molecular nitrogen ( $M \simeq 28$ ).

The ionization region is situated immediately behind the ion source cathode. A specific (small) part of gas atoms and molecules reaching that region is being ionized, and the ions formed are drawn in the region of the radiofrequency analyzer by subsequent grids, where their subdivision by masses takes place.

Upon the opening of the tube at altitudes exceeding 100 km, where the value of the mean length of molecules' free path exceeds the analyzer's dimensions, the gas inside the apparatus continually interacts with the surrounding medium. At the same time, two equal particle fluxes of opposite directions will be passing through the ionization region: the "direct" (from the atmosphere into the tube) and the "reverse" (from the tube into the atmosphere). The particles of these two fluxes do not practically interact with one another (free-molecular flow), and they will substantially differ from the standpoint of their interaction with the walls and electrodes of the mass-spectrometer's tube. If in the direct flow, molecules and atoms not having undergone collisions, may be present to a greater or lesser degree depending upon the orientation of the inlet opening relatively to rocket's velocity vector, all particles of the reverse flux will undergo one or several collisions with the walls, the collector and the grids of the device.

The particle temperature of the reverse flux will obviously be equal to that of the apparatus' walls, and will differ from it for the free atmosphere. As to particle composition of the reverse flux, it will also substantially differ from that of the direct flux and free atmosphere, if the latter contained initially unstable compounds capable to decompose at collisions with the walls and electrodes of the tube\*, or active radicals (atoms) able to recombine or enter in any reactions (for example to form oxides, nitrides or hydrides of a metal) on the surface.

By the strength of the fact that particle ionization of the straight or reverse fluxes takes place with an equal probability, the resulting composition recorded by the apparatus may substantially differ from the composition of the free atmosphere. Thus for instance, if molecular oxygen is absent in the atmosphere (total dissociation  $[O_2]/[O] = 0.$ ) and in the reverse flux all oxygen atoms result recombined into molecules, the resulting relation of atomic and molecular oxygen's concentrations in the ionization region will be  $[O_2]/[O] = 0.5$ . So, the magnitude recorded by the mass-spectrometer that is close to it, may be wrongly interpreted as reflecting the true composition of the atmosphere.

As a result, underrated figures, incompatible with the reality, will be obtained for the degree of molecular oxygen dissociation, while the mean molecular weight of the air determined by these data will be overrated.

This apparently is exactly what took place in the measurements carried out by the USA investigators during the IGY [1]. The values of the mean molecular weight of the air at altitudes to 240 km determined by Townsend according to the data of these measurements [5], must thus be considered as overrated. The close values of the degree of molecular oxygen

dissociation, and consequently of the mean molecular weight of the air, obtained during the three different rocket launchings for substantially different angles of attack of the mass-spectrometer tube (Townsend's argument, see ref. [5]), do not constitute at all the proof of the fact, that oxygen atom recombination process inside the apparatus may be neglected. To the contrary, the opposite point of view is here corroborated: The recombination of atomic oxygen inside the tube takes place nearly to the same degree, regardless of the value of the angle of attack.

The variations of the angle of attack could not be substantially reflected on concentrations of  $O$  inside the tube even in the direct flux, since rocket velocities always were either commensurate with the mean thermal velocities of particles or lower:  $v_p \leq \bar{v}_T$ . The construction of the Townsend apparatus is such (see Fig. 1) that a notable share of particles of the direct flux may reach the ionization region without experiencing collisions with walls, but only in a small range of the angles of attack (from  $0$  to  $11^\circ$ ), and only on condition of a sufficiently high rocket velocity ( $v_p > \bar{v}_T$ ). In rocket experiments with a 250 km top trajectory this inequality is not fulfilled: at  $T = 1000^\circ K$  the mean thermal velocity of the oxygen atom <sup>is</sup>  $\bar{v}_T = 10^3$  m/sec, and the rocket velocity at 100 km altitude is  $v_p = 1.7 \cdot 10^3$  m/sec, and at 220 km it is  $v_p = 0.8 \cdot 10^3$  m/sec.

All the above-said is also valid as regards rocket measurements of the neutral composition carried out by A. A. Pokhunkov [2, 6], inasmuch as the construction of the apparatus as well as the measurement method do not differ substantially from those described in references [1, 5].

For the reasons expounded the obtained value of the mean molecular weight of the air at 200 km altitude (26.6 g/mole, [6]), just as are the values of relative concentrations of molecular oxygen at 100 - 211 km altitudes, are apparently overrated. The values of atomic oxygen concentrations at the same altitudes are probably underrated.

As a complementary argument, there are the results of optical measurements of density of molecular oxygen in the atmosphere according to absorption of ultraviolet radiation of the Sun at altitudes to 180 km, obtained with the help of photometers aloft on rockets [7]. According to these measurements, the  $O_2$  concentration in the atmosphere in the interval from 110 to 180 km drops 400 times:

Altitude in kilometers	110	120	130	150	160	170	180
$[O_2] \cdot 10^{10} \text{ cm}^{-3}$	16	3.0	1.0	0.4	0.14	0.08	0.04

These results diverge substantially from the data supplied by mass-spectrometric measurements of the composition of the atmosphere. It follows from [1, 2, 5, 6], that  $O_2$  is reliably registered by the mass-spectrometer at all rocket flight altitudes through 210 + 220 km, while according to data of optical measurements, the concentration becomes close to the limit of that detectable by mass-spectrometer, i. e. of the order of  $10^8 \text{ cm}^{-3}$ , already at 180 km altitude [2, 6].

Possible Ways of overcoming these Difficulties. In order to obtain full-fledged data on the upper atmosphere gas content, including data on the degree of dissociation of molecular oxygen and nitrogen, on atomic hydrogen concentration, and on that of unstable compounds of the OH type, etc., it

is necessary, as already stated, that the direct flux from the atmosphere hit the ionization region without preliminary collisions with the ion source cathode, with electrodes, and with the walls of the tube, and that the reverse flux' particles, having experienced collisions with the cathode, the walls and the electrodes, did not undergo as a result any changes, or did not reenter the ionization region.

The requirement relative to the absence of interactions between the direct flux and the ion source cathode is easily fulfilled. It is indicated to remove the cathode from the path of the inflowing gas by changing the layout of the ion source in such a way that the electron beam be perpendicular to the molecular bundle, and by separating the cathode from the ionization region by appropriate diaphragms. It is well known that the ion sources of magnetic mass-spectrometers are built according to that principle. If at the same time a good "exhaustion" of the ion source region is assured, i.e. the gas exchange with the surrounding space, a complementary possibility of substantially increasing the cathode power will result without the fear of limiting the apparatus' sensitivity by the appearance of an undesirable "background" of cathode and electrode emanations. At the same time the emission current will intensify, which is equivalent to the increase in mass-spectrometer's sensitivity.

The second requirement — the elimination of reactions on the electrode surfaces, and on the walls of the tube of the analyzer — is considerably more difficult to satisfy.

Measurements on Rockets. Under conditions of rocket experiments for which comparatively small relative velocities are characteristic

$v_p \sim (1 \div 3) \cdot 10^5$  cm/sec, one may not fear molecular constituent dissociation in the apparatus at collisions with the walls. However the danger of atom recombination, and that of the binding of active constituents in combinations on the surfaces remains. It is hardly appropriate to attempt to account for all those complex and diversified reactions which may take place between particles of the gas phase and preliminary adsorbed atoms, and nitrogen and oxygen molecules or compounds formed on the surfaces. As is well known, the rates of similar reactions depend to a greater degree on the chemical nature of the surface, as well as on its state, the degree of purity and degasification. (see for example reference [8]).

The selection of proper construction materials or coverings for the walls of the bulb for analyzer's electrodes would be of some use despite it being a palliative way to remedy the situation. Certain of these measures may to a certain extent decrease the variation in the composition of the reverse flux, although atom recombination into molecules can hardly be entirely eliminated. Thus, for instance, according to reference [9], the values of atoms' H and O recombination coefficients on the surface for all investigated coverings (oxides of chromium, magnesium, molybdenum, zinc and lead) lie within the range  $4 \cdot 10^{-2} \div 1 \cdot 10^{-4}$ , strongly varying in dependence upon the type of gas. The nitrogen atom recombination coefficients on the surface (Pt, LiCl, PbO) also are extremely high ( $1 \cdot 10^{-2} \div 4 \cdot 10^{-2}$ ), see reference [3].

In our opinion, the only radical measure is the introduction of an effective exhaustion of the analyzer region similarly to what was already done (for other purposes) for the magnetic mass-spectrometer on a rocket [10].

At the same time, the apparatus' construction must be substantially modified. Considerable technical and technological difficulties may be anticipated here.

A quite different approach may be made for the solution of the problem set up. It is possible to attempt to distinguish the direct and reverse fluxes, taking advantage of the difference in velocities of particles constituting them. What is really meant is the possible distinction of mean thermal velocities, as well as the presence of a regulated velocity in the particles of the direct flux.

Measurements on Satellites. The distinction in regulated velocities is particularly easy to utilize during experiments on the Earth's artificial satellite. In this case the difference in the velocities of the direct and reverse fluxes

$$v = v_{\text{sat}} \left[ 1 + (1 - \rho)^{\frac{1}{2}} \right],$$

where  $\rho$  is the accommodation coefficient, and it may lie within the range from 8 to  $\sim 20$  km/sec ( $v_{\text{sat}} = 8 \div 10$  km/sec). Because of the fact, that even at elastic collision with the electron, the impulse variation of the particle  $M$  will be of the order of the relation of electron masses and particles —  $\Delta(Mv) \sim m_e/M < 10^{-3}$ , this difference in velocities will be preserved in the direct and reverse fluxes' ionized particles too, these particles appearing in the region of apparatus' ionization.

Consequently, the positive ions of the direct flux, having the mass number  $M$ , and the charge  $q = 4.3 \cdot 10^{-10}$  un. CGSE, will be endowed in the analyzer with energy, excessive in comparison with that of reverse flux' ions, and equivalent to the presence of a certain accelerating difference



For ions formed from particles of the direct flux,  $\Delta V_v < 0$ , and for the ions of the reverse flux  $\Delta V_v \geq 0$ . Correspondingly to this the effective decelerating potential of radio-frequency mass-spectrometer for particles of the direct flux will result underrated by the magnitude  $\Delta V_v$ , and it will be unchanged or overrated, depending upon the value for the reverse flux particles

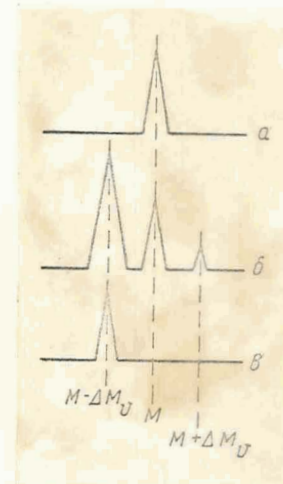
$$U_{\text{eff.dec.pot.}} = U_{\text{dec.pot.}} + \Delta V_v, \quad (2)$$

where  $U_{\text{dec.pot.}}$  is the nominal value of the decelerating potential, fixed during the tuning of the apparatus in the laboratory.

The mass peaks in spectra registered by the mass-spectrometer on the satellite, will result shifted on the apparatus' scale toward the light masses for particles of the direct flux (similarly to the way it takes place in the case of the ion analysis [11]), and toward heavy masses for the reverse flux particles, having experienced reflection with the accommodation coefficient  $\rho < 1$ . The mass peaks of reverse flux particles having reflected with the accommodation coefficient  $\rho = 1$ , will not experience any shift on the scale.

Fig. 2, a — Spectrum of masses given by the radio-frequency device (one component with the mass number  $M$ ). The device is immobile.

б — same, but the device is shifting with a great speed; its axis is directed along the velocity vector; B — same as in "б", but a variable decelerating potential is introduced in the device.



Let us exemplify the above-said. In a Bennett-type radio-frequency mass-spectrometer the separation by masses is achieved by variation of the accelerating voltage. Under laboratory conditions the mass number is determined by the formula

$$M = \frac{V}{k} \quad (3)$$

where  $M$  is the peak number expressed in a.m.u.,  $V$  is the value of voltage acceleration in volts at time of peak occurrence, and  $K$  is the constant of the device (of the order of  $5 \text{ -- } 10 \text{ v/amu}$ ).

In view of the fact that the apparatus works as a velocity filter, allowing the passing through the collector<sup>of</sup> only the ions accelerated by the voltage  $V$  up to a certain specific "synchronous" flight velocity, ions with the mass number  $M$  will be accelerated to the synchronous velocity during the analysis of the composition of gas atmosphere on the satellite at different acceleration voltage, depending on whether the particles belong to the direct or to the reverse flux with  $\rho = 0$  or  $\rho = 1$ . The occurring mass spectrum is represented in Fig.2.

As follows from (1) and (3), the mass shifts of the peaks then are:

$$M_v = V_v/k = \mp 300 M_0 (1 - \rho) v_{\text{sat}}^2 / 2qk \quad (4)$$

The magnitudes  $\Delta M_v$  are also compiled in the Table.

The obtained three peaks of one component  $M$  may be resolved if the resolving capacity of the device is sufficiently great, i.e. if the condition

$$R = M/\Delta M \gg 2qk/300m_0 (1 - \beta) v_{\text{sat}}^2. \quad (5)$$

is fulfilled.

Substituting the numerical values of the magnitudes, and assuming  $v_{\text{sat}} = 8 \cdot 10^5$  cm/sec, and  $\beta = 0$ , (condition which always take place for the direct flow), we have

$$R \geq 3k \quad (5')$$

This inequality is fulfilled at the usually encountered parameters of the apparatus. For example, at  $k = 7$ , resolution  $R$  must exceed 21, which is easily reached, at least for the mean mass number values  $M = 12 \text{ -- } 60$  a.m.u. [2, 6].

Therefore, the problem of separating the direct and the reverse fluxes by radio-frequency mass-spectrometer on a satellite is easily solved on condition that the analyzed gas consist of a single component, or of several, with a difference in mass numbers

$$M_1 - M_2 \geq 2\Delta M.$$

This inequality is not even fulfilled for the basic components, at least at not too high altitudes, in the terrestrial atmosphere (there are close according to mass numbers, molecular and atomic nitrogen and oxygen see the Table). The superimposition of direct and reverse fluxes' peaks of various components may only be avoided in this case by taking advantage of the circumstance, that the effective decelerating potential for the direct flow will be lowered by the magnitude  $\Delta V_v$ , (see (2), with  $\Delta V_v < 0$ ).

This is reflected in Figure 2. The amplitude of the direct flux' peak exceeds the peaks of reverse particle flux, for the level of the decelerating potential of the mass-spectrometer is normally maintained constant. The resolution for the peak of direct flux' particles is becoming worse than the nominal.

The peaks of the reverse flux may be suppressed by raising the  $U_{\text{dec pot}}$  by the magnitude  $\Delta V_v = 300 M m_0 v_{\text{sat}}^2 / 2q$  volts, i. e. by introducing the alternating decelerating potential, independent from the mass number value to which the apparatus has been tuned:

$$U_{\text{dec pot}} = U_{\text{dec pot}_0} + 390 M m_0 v_{\text{sat}}^2 / 2q = U_{\text{d p}_0} + k_1 V/k, \quad (6)$$

where  $k_1 \equiv 300 m_0 v_{\text{sat}}^2 / 2q = 0.332 \text{ v/amu}$  for  $v_{\text{sat}} = 8 \cdot 10^5 \text{ cm/sec}$ ,

and  $k_1 = 0.519 \text{ v/amu}$  for  $v_{\text{sat}} = 1 \cdot 10^6 \text{ cm/sec}$

At the same time, another fairly important advantage is revealed in addition, consisting in the fact that a normal regime, according to the decelerating potential, will be sustained for the peaks of the direct flux' particles independently from the value of the mass number, i. e. a nominal resolution will be preserved in the total absence of harmonic peaks in the spectrum.

The peaks of the reverse flux' particles, having reflected with  $\varphi = 1$  (and with  $\varphi = 0$  a fortiori), may be totally locked if at the introduction of the alternating deceleration potential according to (6), the following condition is fulfilled:

$$U_{\text{dp}} - U_{\text{dp}_0} = V_v > (1 - K) 2.05 \text{ PU}_{\text{eff.hf.}} \quad (7)$$

This is understandable insasmuch as the right-hand expression represent the value of ion energy, having passed the potential barrier of the device's decelerating grid for the case of an immobile analyzer. Here  $U_{\text{eff. hf}}$  is the effective value of hf voltage on the analyzer's grids.  $P$  is the number of cascades in the analyzer;  $K$  is the magnitude characterizing the relative level of the deceleration potential:

$$K = U_{\text{dp}_0} / U_{\text{max dp}}$$

$U_{\text{max dp}}$  being the peak cutoff potential.

Condition (7) means that the regime of the apparatus at high frequency cannot be arbitrary, while for the mass peak cutoff of the reverse flux' particles, the fulfillment is required of the following condition:

$$U_{\text{eff hf}} < 300 M m_0 v_{\text{sat}}^2 / 2.05 P q (1 - K). \quad (8)$$

For a three-cascade analyzer ( $P = 3$ ), assuming  $k = 0.85$  with the velocity  $v_{\text{sat}} = 8 \cdot 10^5$  cm/sec, we have

$$U_{\text{eff. hf}} < 0.362 M. \quad (8')$$

Therefore, in order to obtain undistorted spectra characterizing the composition of the atmosphere containing atomic nitrogen and oxygen ( $M = 14$ ,  $M = 16$ , respectively), the effective high-frequency voltage of the mass-spectrometer on the satellite must not exceed  $\sim 5$  volts.

The advantages of the recommended operating regime for the mass-spectrometer on the satellite is schematically illustrated in Fig. 2. At the introduction of the alternating deceleration potential, and also on the condition of a proper selection of the high-frequency amplitude,

the mass peaks of particles of the reverse flux are totally locked in and are not registered. Only the mass peak belonging to the component's M direct particle flux, reproducible with a nominal resolution, remains in the spectrum.

It must be especially underlined that in the described operating regime, the mass-spectrometer will also be insensitive to molecules of compounds having formed as a result of reactions on the hot cathode of some of the atmospheric constituents, as well as to the "gassing" background of the cathode, and of electrodes, and of the walls of the tube, including the satellite itself.\* The difficulties connected with the presence of all these upsetting factors, and the distortions of the true composition of the atmosphere, as well as the limitations of the useful (effective) sensitivity of the mass-spectrometer will not take place.\*\*

The true mass number of peaks of direct flux' neutral atmospheric components to be registered by the mass-spectrometer on the satellite, may be determined, as this results from the correlations (1), (3) and (4), by the formula

$$M = \frac{V + \Delta V_v}{k} = M_{\text{dem}} + \Delta M_v = \frac{M_{\text{dem}}}{1 + 300 m_0 v_{\text{cn}}^2 / 2qk} \quad (9)$$

Here  $M_{\text{dem}}$  — is the mass number of the peak determined at deciphering the recording of the value of voltage acceleration V at time of its appearance.

\* Naturally, not at an excessive "gassing" density.

\*\* It is essential to note, that the possibility of selecting such regime is a great advantage of a radio-frequency device as compared with f.e. a magnetic mass-spectrometer, whose reaction will be similar for the direct unperturbed atmosphere particles, as well as the inverse and gassing molecules.

$M_v$  is the correction accounting for the velocity of the satellite.

A similar formula for the determination of the true mass number of peaks of atmospheric ions [11] is only distinguished by the term accounting for the satellite's potential :

$$M^+ - \frac{V + \Delta V_v + \varphi}{k} = M_{\text{dec}}^+ + \Delta M_v^+ + \Delta M_\varphi^+ = \frac{M_{\text{dec}}^+ + \varphi/k}{1 + 300 \frac{v_{\text{cn}}^2}{2qk}} \quad (10)$$

It follows from the comparison of (9) and (10), that when the mass-spectrometer operates in the described regime, the difference, obtained at time of switching the apparatus in sequence from the analysis of the neutral component of the atmosphere to that of the ion component and vice-versa, between the values of the mass numbers obtained for neutral and ionized particles of the same mass by deciphering (for example of neutral and ionized atomic oxygen, O and O<sup>+</sup>) will only be determined by the satellite's potential, and will not be dependent on other factors, such as the variations of the apparatus' electric regime, variations in satellite's velocity and so for). Thus the potential  $\varphi$  of the satellite may be determined from the correlation:

$$\varphi/k = M_{\text{dec}} - M_{\text{dec}}^+ \quad (11)$$

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1. Measurements of gas composition of the atmosphere effected to-date above 100 km altitude with the help of radio-frequency mass-spectrometer installed on rockets do not yield a correct representation on the degree of dissociation of the basic atmosphere constituents — O and N,

and they therefore cannot serve as initial data for the determination at various altitudes of the molecular weight of the air.

In order to solve this fundamental problem, the method of measurements by means of a radio-frequency mass-spectrometer must be substantially improved.

2. Measurements of gas composition of the atmosphere with the aid of a radio-frequency mass-spectrometer on an Earth's artificial satellite may provide undistorted data on atmosphere composition, including those on the degree of dissociation of oxygen and nitrogen at satellite's flight altitude, provided special changes are made in the apparatus so as to introduce the alternating deceleration potential, and diminish the high-frequency voltage.

It is essential that in the recommended operating conditions, the effective mass-spectrometer's sensitivity be not limited to the background of the apparatus' and satellite's "gassing".

3. Data on satellite's potential may be obtained at periodical switching of the apparatus from the analysis of the neutral gas composition to that of ion composition and vice-versa.

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\* These names are transliterated.